means for separating said echo signals into fundamental and harmonic frequency components; and

an image processor which produces image signals which are a blend of proportions of said fundamental and harmonic frequency components, said proportions being predetermined to vary [varying] with echo signal depth.

2. (Amended) [The ultrasonic diagnostic imaging system of Claim 1,] An ultrasonic diagnostic imaging system for producing a blended harmonic ultrasonic image of tissue inside a body, comprising:

means for transmitting ultrasonic energy into the body at a fundamental frequency;

means, responsive to said transmitted ultrasonic energy, for receiving ultrasonic echo signals from tissue at a plurality of depths in the body;

means for separating said echo signals into fundamental and harmonic frequency components; and

an image processor which produces image signals which are a blend of proportions of said fundamental and harmonic frequency components, said proportions varying with echo signal depth,

wherein said image processor comprises means for producing image signals of predominately harmonic frequency components in the near field of an image, and image signals of predominately fundamental frequency components in the far field of an image.

5. (Amended) [The ultrasonic diagnostic imaging system of Claim 4,] An ultrasonic diagnostic imaging system for producing a blended harmonic ultrasonic image of tissue inside a body, comprising:

means for transmitting ultrasonic energy into the body at a fundamental frequency;

means, responsive to said transmitted ultrasonic energy, for receiving ultrasonic echo signals from tissue at a plurality of depths in the body;

means for separating said echo signals into fundamental and harmonic frequency components; and

an image processor which produces image signals which are a blend of proportions of said fundamental and harmonic frequency components, said proportions varying with echo signal depth,

wherein said separating means includes a filter for producing fundamental frequency echo signal components to the at least partial exclusion of harmonic frequency

<u>components, and for producing harmonic frequency echo signal components to the at least partial exclusion of fundamental frequency components,</u>

wherein said transmitting means comprises means for transmitting two differently phased pulses of ultrasonic energy to a common region of the body, and

wherein said filter combines ultrasonic echoes from said two transmitted waves to produce at least one of said fundamental and harmonic frequency echo components.

6. (Amended) [The ultrasonic diagnostic imaging system of Claim 1,] <u>An ultrasonic diagnostic imaging system for producing a blended harmonic ultrasonic image of tissue inside a body, comprising:</u>

<u>means for transmitting ultrasonic energy into the body at a fundamental frequency;</u>

<u>means, responsive to said transmitted ultrasonic energy, for receiving ultrasonic echo signals from tissue at a plurality of depths in the body;</u>

<u>means for separating said echo signals into fundamental and harmonic frequency components; and</u>

<u>an image processor which produces image signals which are a blend of proportions of said fundamental and harmonic frequency components, said proportions varying with echo signal depth,</u>

wherein said image processor comprises means for producing a fundamental image from said fundamental frequency components and a harmonic image from said harmonic frequency components,

wherein said image processor produces a blended image which is a combination of image signals from said fundamental and harmonic images.

7. (Amended) An ultrasonic diagnostic imaging system for producing a blended harmonic ultrasonic image of tissue inside a body, comprising:

a transducer for receiving ultrasonic echoes from tissue in an image area of the body <u>in the absence of an ultrasonic contrast agent</u>, said ultrasonic echoes containing fundamental and harmonic frequency components; and

an image processor, responsive to said ultrasonic echoes, for producing an image of said image area which is a variable blend of fundamental and harmonic frequency information.

13. (Amended) A method for producing an ultrasonic image which is a blend of fundamental and harmonic frequency echo information comprising the steps of:

receiving ultrasonic echoes from tissue of the body <u>in the absence of an ultrasonic contrast agent</u> which contain both fundamental and harmonic frequency components;

separately detecting said fundamental and harmonic frequency components of said ultrasonic echoes;

forming signals which are a blend of said detected fundamental and harmonic frequency components prior to image formation;

storing said signals in a blended image memory; and

displaying an image from the signals stored in said blended image memory.

26. (Amended) A method for producing an ultrasonic image which is a blend of fundamental and harmonic frequency echo information comprising the steps of:

receiving from a range of depths a sequence of ultrasonic echoes from tissue of the body which contain both fundamental and harmonic frequency components;

separating said fundamental and harmonic frequency components of said ultrasonic echoes;

forming signals corresponding to said range of depths which are a varying composition of said fundamental and harmonic frequency components <u>with depth</u>; and

displaying an image produced from said signals.

27. (Amended) [The method of Claim 26,] <u>A method for producing an ultrasonic image which is a blend of fundamental and harmonic frequency echo information comprising the steps of:</u>

<u>receiving from a range of depths a sequence of ultrasonic echoes from tissue of the body which contain both fundamental and harmonic frequency components;</u>

<u>separating said fundamental and harmonic frequency components of said ultrasonic echoes;</u>

<u>forming signals corresponding to said range of depths which are a varying composition of said fundamental and harmonic frequency components; and</u>

<u>displaying an image produced from said signals,</u>

wherein said step of forming forms signals primarily composed of harmonic frequency information at a shallow depth, and forms signals primarily composed of fundamental frequency information at a deeper depth.

Add new Claims 28-41 as indicated below:

28. (Newly added) An ultrasonic imaging method comprising:

transmitting ultrasonic energy to a target, said ultrasonic energy characterized by a peak power level in a fundamental frequency band;

receiving ultrasonic echo information associated with said transmitted ultrasonic energy in first and second frequency bands, said first frequency band comprising said fundamental frequency band, said second frequency band comprising a harmonic of said fundamental frequency band and substantially excluding said fundamental frequency band;

forming a composite image in response to said received ultrasonic echo information, said composite image comprising spatially distinct near-field and far-field regions, said far-field region emphasizing echo information in the first frequency band and said near-field region emphasizing echo information in the second band.

29. (Newly added) An ultrasonic imaging method comprising the following steps:

(a) acquiring fundamental mode ultrasonic image signals and harmonic mode ultrasonic image signals from a scanned region with a transducer;

(b) combining the fundamental and harmonic mode image signals of step (a) to form a composite image, said composite image comprising a first predetermined image region that is modulated primarily as a function of the fundamental mode ultrasonic image signals and a second predetermined image region that is modulated primarily as a function of the harmonic mode ultrasonic image signals.

30. (Newly added) The ultrasonic imaging method of Claim 29, wherein acquiring harmonic mode ultrasonic image signals is performed in the absence of an ultrasonic contrast agent in the scanned region.

31. (Newly added) A medical ultrasonic diagnostic composite image comprising:

a first predetermined image region modulated primarily as a function of fundamental mode ultrasonic image signals acquired from a portion of a subject;

a second predetermined image region modulated primarily as a function of harmonic mode ultrasonic image signals acquired from a portion of the subject.

32. (Newly added) The medical ultrasonic diagnostic composite image of Claim 31, wherein the harmonic mode ultrasonic image signals are acquired in the absence of an ultrasonic contrast agent.

33. (Newly added) An ultrasonic imaging system comprising:

means for acquiring fundamental mode ultrasonic image signals and harmonic mode ultrasonic image signals from a scanned region with a transducer;

means for combining the fundamental and harmonic mode image signals to form a composite image, said composite image comprising a first predetermined image region that is modulated primarily as a function of the fundamental mode ultrasonic image signals and a second predetermined image region that is modulated primarily as a function of the harmonic mode ultrasonic image signals.

34. (Newly added) The ultrasonic imaging system of Claim 33, wherein the means for acquiring acquires the harmonic mode ultrasonic image signals in the absence of an ultrasonic contrast agent in the scanned region.

35. (Newly added) An ultrasonic imaging method comprising the following steps:

(a) acquiring fundamental mode ultrasonic image signals and harmonic mode ultrasonic image signals with a transducer;

(b) combining the fundamental and harmonic mode image signals of step (a) to form a composite image, said composite image comprising a first image region that is modulated primarily as a function of the fundamental mode ultrasonic image signals, a second image region that is modulated primarily as a function of the harmonic mode ultrasonic image signals, and a compound image region that is modulated as a function of both the fundamental mode image signals and the harmonic mode image signals, the compound region being intermediate of the first and second image regions.

36. (Newly added) The ultrasonic imaging method of Claim 35, wherein the step of acquiring further comprises acquiring harmonic mode ultrasonic image signals in the absence of an ultrasonic contrast agent.

37. (Newly added) A medical ultrasonic diagnostic imaging system adapted to provide a composite image comprising:

a first image region modulated primarily as a function of fundamental mode ultrasonic image signals;

a second image region modulated primarily as a function of harmonic mode ultrasonic image signals; and

a compounded region, intermediate the first and second image regions, said compounded region modulated as a function of both the fundamental mode image signals and the harmonic mode image signals.

38. (Newly added) The medical ultrasonic diagnostic imaging system of Claim 37, wherein the harmonic mode ultrasonic image signals are acquired in the absence of an ultrasonic contrast agent.

39. (Newly added) An ultrasonic imaging method comprising the following steps:

(a) acquiring fundamental mode ultrasonic image signals and harmonic mode ultrasonic image signals with a transducer in the absence of an ultrasonic contrast agent;

(b) combining the fundamental and harmonic mode image signals of step (a) to form a composite image, said composite image comprising a first image region that is modulated as a function of the fundamental mode ultrasonic image signals and a second image region that is modulated primarily as a function of the harmonic mode ultrasonic image signals.

40. (Newly added) A medical ultrasonic diagnostic imaging system adapted to provide a composite image of a subject comprising:

a first image region modulated primarily as a function of fundamental mode ultrasonic image signals acquired from a first region of the subject; and

a second image region modulated primarily as a function of harmonic mode ultrasonic image signals acquired from a second region of the subject in the absence of an ultrasonic contrast agent.

41. (Newly added) An ultrasonic imaging system comprising:

means for acquiring fundamental mode ultrasonic image signals and harmonic mode ultrasonic image signals with a transducer in the absence of an ultrasonic contrast agent;

means for combining the fundamental and harmonic mode image signals to form a composite image, said composite image comprising a first image region that is modulated primarily as a function of the fundamental mode ultrasonic image signals and a second image region that is modulated primarily as a function of the harmonic mode ultrasonic image signals.

REMARKS

Claims 1, 3-4, 7-16 and 26 were rejected under 35 U.S.C. §103(a) as being unpatentable over US 5,526,816 (Arditi). Certain ones of these claims have been amended to more clearly define the present invention in view of Arditi, who is trying to improve the contrast in contrast agent images.

The claimed invention describes an ultrasound system and method for producing blended fundamental and harmonic images, thus taking advantage of the imaging characteristics of both types of information in a single image. Claim 7 for instance has a transducer for receiving ultrasonic echoes in the absence of a contrast agent which contain fundamental and harmonic signal components. An image processor is responsive to the echoes for producing an image which is a variable blend of fundamental and harmonic frequency information. Claim 13 is representative of a method of the present invention and comprises receiving echoes which contain both fundamental and harmonic components, separately detecting the components, forming signals which are a blend of the detected components, storing the blended components, and displaying an image containing the blended components.

Arditi is trying to improve the contrast of contrast agent images. His techniques do not apply in the absence of contrast agents, where they would provide no advantage (col. 5, lines 35-40.) His techniques generate a parameter produced from different frequencies chosen based upon the response of tissue and the resonant frequency of microbubbles of the contrast agent. The microbubble resonant frequency he is using is not a harmonic frequency, but a lower resonant frequency. Arditi makes this clear in col. 6, lines 15-21 where he states that his invention does not require any nonlinearity. In col. 9, lines 19-24 he states that f_r is the resonant frequency of microbubbles, and that when the excitation amplitude is such that non-linear oscillation occurs, energy is also backscattered at the frequency of the second harmonic.